A Graph method for mapping changes in temporal and spatial phenomena with relativistic consequences

Daniel Brown[1]
Depts of Physics and Astronomy and Computer Science
University College London
Gower Street London WC1E 6BT, U.K.

February 7, 2008

Abstract

A cellular automata approach (using a Directed Cyclic Graph) is used to model interrelationships of fluctuating time, state and space. This model predicts phenomena including a constant and maximum speed at which any moving entity can travel, time dilation effects in accordance with special relativity, relativistic Doppler effects, propagation in three spatial dimensions, an explanation for the non-local feature of collapse and a speculation on an explanation for gravitation effects. The approach has proven amenable to computer modelling.

A further paper details the statistical implications for identifying the probability of locating a particle at a particular position in space.

[1]email: d.brown@cs.ucl.ac.uk

1 Introduction

Minsky (1982) investigated a model of the universe using "a crystalline world of tiny, discrete 'cells', each knowing only what its neighbours do". In Minsky's model properties such as a maximal speed emerge. However, Minsky found that the model rapidly lost coherence requiring increasing additional rules and the wrong time dilation factors emerged. Feynman (1982) also examined cellular automata models and was particularly concerned with simulating time on computers using a model of discrete time; he noted that "a very interesting problem is the origin of the probabilities in quantum mechanics". Recent research, such as Jaroskiewicz (2000) has resurrected analysis of cellular automata using an approach centred on the evaluation of non-local information. The current paper addresses these issues through a cellular automata method using several dimensions of time. Whilst Tegmark (1997) considered that 3 dimensions of space with more than one dimension of time produces "unpredictable" artifacts such as backward causation, this paper aims to demonstrate that this is not necessarily the case if the time dimensions are appropriately formulated.

2 Background

Explanations for a number of physical phenomena remain unexplained. These include wave/particle "duality", the reason for a maximum possible speed and "action at a distance" effects. This paper resolves these phenomena through an analysis of the nature of *changes in time*.

To model these changes, the approach has two features of particular note: it is distributed and logical precedence has priority over all other conditions (including temporal precedence). It uses directed (cyclic) graphs; Pearl notes this is an excellent apparatus for study since "causality has been mathematicised" (Pearl 2000) - and they lead naturally to Markov modelling.

A graph comprises a collection of entities (or nodes or vertices) connected together by links (edges). The value of any entity can be measured, but to predict its value the values of other interrelated entities and the rules for their combination have to be known also.

An Entity is defined through four principal components: its *elements*, the *rules* which govern the cycle between these elements, the *links (or triggers)*

that initiate cycling between elements, and the *constellation* which maps the links to other entities in the graph.

A constellation of linked changing entities establishes an Interrelated Fluctuating Entity (IFE) disturbance.

Each Entity contains a set of elements e.g. (0,1,2,3,4,5). An entity has a minimum of 2 elements and no maximum. Once triggered (by a link from another entity) the entity can be set to cycle through its sequence of elements as follows:
(i) cycle forward a single element only until a further trigger
(ii) cycle through the complete set of elements
(ii) cycle backward through the set of elements
(iii) On reaching a specified element value (e.g. 5) the entity can be determined to:

(a) return directly to the first element
(b) cycle in steps back to the first element (1,2,3,4,5,4,3,2,1)
(c) remain at the specified element value

A graph *links* two or more separate entities. An entity starts cycling through its elements when triggered by a specified change in a linked entity. All links between IFEs are directed (a trigger by one entity logically activates the cycling of another entity) and can be cyclic (e.g. where an element in X triggers an element in Y and an element in Y triggers an element in X). An entity can be determined to trigger an adjacent entity:
(i) By any change in element value
(ii) By passing a specific element value
An important link is via a "trigger" threshold value p. Thus the entity Space=(1,2,3,4,5) can be set to trigger the entity Time=(1,2,3,4,5,6,7,8,9) when Space reaches the Space→Time-change trigger value p=4.

Example: how to establish a wave/particle disturbance

A graph can model a moving disturbance. A simple example of this is a row of football fans creating a "Mexican Wave" in a stadium (similar to a model for a series of falling dominoes). We can model the fans using a wave pattern through a sine function, but for the fans themselves it is easier to use a set of simple rules such as the following... If the first fan starts to stand up, then once this fan reaches a certain height this triggers the spatially adjacent fan to start standing, which triggers the next fan...

Likewise, with five dominoes laid out in a one dimensional row, if we tip the first one over to the right then the next to its right will fall, which triggers

the next one to fall...

The entity "State" is defined as $R = \{0, h, 2h, 3h\}$ where 0 indicates an upright domino, h indicates a tipping domino, 2h indicates a domino tipping further and 3h indicates a horizontal fallen domino.

The entity "Space" is defined as $x = \{0, 1, 2, 3, 4\}$ where 0 indicates the first spatial position, 1 the next spatial position to the right etc...Each of the 5 spatial positions is therefore an equal distance dx=1 units apart. Because State and Space have finite numbers of elements, then by applying rule 2.(iii)(c), entities will eventually remain fixed on their final elements.

The entity "Time" is defined as the infinite set of elements T = $\{0, 1, 2, 3, 4, ...\}$

The Space, Space and Time entities interrelate in the domino graph: ((R),x,T). - The extra bracket for R indicates a distinct State *entity* for each *element* of Space and Time.

A directed link from State to Time is defined such that *any* change in State triggers a change in Time $d\alpha$. This is the State→Time link.

A directed link from Time to State is defined such that *a change in time of s units* triggers a change in State (i.e. "it takes s units of time to transition from one State to the next"). This is the Time→State link

A directed link from State to Space is defined such that a change of State **only where R'=ph** at a spatial position x triggers a change in Time element $d\beta$ at the *adjacent* spatial position x', with the time measure but not the State carried forward to this next spatial position[2]. This is the State→Space link.

To establish the time at any given point in Space and State, for the moment it is simply assumed that $T = \alpha + \beta$; however this is an assumption that will be dispensed with later. The graph layout is therefore:

State(R) → Space(x)
↓ ↑ ↓
Time(T)

The logical rules for this algorithm, where → signifies a transition, T^+

[2]Triggering a change in domino State at an adjacent spatial position is equivalent to a change in Space(dx) followed by a change in State(dR). We can theoretically dispense with the physical structure and regard the spatial layout abstractly as itself an IFE which interacts with the IFEs of State and Time. Both Time and Space then form variable pointers of an array (x,T) which contain a value of State(R). Hence a change in Time preserves a continuity in State at the new (x,T), but a change in Space does not.

indicates the adjacent successor of T and $\supset$ indicates a *logical* implication using declarative programming, are - where (R, x, T) indicates coordinates of (State,Space,Time):

1. a change in State dR of $\{(R, x, T) \rightarrow (R^+, x, T)\} \supset$ a change in Time dT such that $\{(R^+, x, T) \rightarrow (R^+, x, T^+)\}$

2. a change in Time dT of $\{(R, x, T) \rightarrow (R, x, T^+)\} \supset$ a change in State dR such that $\{(R, x, T^+) \rightarrow (R^+, x, T^+)\}$

3. a particular change in State dR where R^+=h of $\{(0, x, T) \rightarrow (h, x, T)\} \supset$ a change in Time at a spatially adjacent adjacent IFE such that $\{(0, x^+, 0) \rightarrow (0, x^+, T^+)\}$ (where $T^+ = T + dT$)[3].

Selecting p=1 and s=10, and assuming an initiating trigger of $(0, 0, 0) \rightarrow (0, 0, h)$, the disturbance therefore advances:

$$\begin{array}{l}
(0,0,0) \rightarrow (h,0,0) \rightarrow (h,0,10) \rightarrow (2h,0,10) \rightarrow (2h,0,20) \rightarrow (3h,0,20) \\
\qquad\qquad\qquad\quad \downarrow \\
\qquad\qquad\qquad\quad \rightarrow (0,1,10) \rightarrow (h,1,10) \rightarrow (h,1,20) \rightarrow (2h,1,20) \\
\qquad\qquad\qquad\qquad\qquad\qquad\qquad \downarrow \\
\qquad\qquad\qquad\qquad\qquad\qquad\qquad \rightarrow (0,2,20) \rightarrow (h,2,20) \\
\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad \downarrow \\
\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad \rightarrow (0,3,30) \rightarrow
\end{array}$$

Some points are worth making here.

1. We could choose to follow either the moving disturbance advancing across space $(h, 0, 0) \rightarrow (0, 1, 10) \rightarrow (h, 1, 10) \rightarrow (0, 2, 20) \rightarrow (h, 2, 20)$..., or the disturbance advancing through States in a stationary space position $(0, 0, 0) \rightarrow (h, 0, 0) \rightarrow (h, 0, 10) \rightarrow (2h, 0, 10) \rightarrow (2h, 0, 20) \rightarrow (3h, 0, 20)$. Ambiguity arises in the identity of a disturbance since a change in State of $0 \rightarrow 1$ results in both a Space change and a Time change which results in a further change in State. The progress of the disturbance therefore bifurcates[4].

[3] this is equivalent to the Time entity incrementing and moving in spatial position i.e. $(0, x, T) \rightarrow (0, x^+, T^+)$

[4] This is illustrated by the celebrated paradox of the ship of Theseus. Over a period of time in order to repair a wooden ship (Ship 1) its planks are replaced one by one - but in addition the original planks are taken aside and reconstituted in identical architecture into another ship at a different location (Ship 2). Which ship is the original ship of Theseus... - To decide, we must define our criterion of identity: either continuity of matter over changing space and time (Ship 2) or continuity of space over changing matter and time

2. The sequence of the algorithm steps is important. A change in Time associated with a change in State occurs logically prior to a change in Time due to a change in Space. However, temporally both time changes occur in parallel "at the same time".

3. Time is constructed as an entity which moves independently, "ahead" of the State change.

4. The precedence of logical change over temporal change permits both (R, x, T) and (R^+, x, T). So 2 distinct states (momentarily) coexist at the same spatial and temporal position, logically prior to the logically subsequent temporal transition.

5. At a given time e.g. 10 there are in fact a total of 4 states associated with the disturbance located over 2 spatial positions. These are: (h,0,10), (2h,0,10), (0,1,10), (h,1,10. For a given time 20, the State and Space positions become even more uncertain.

6. Each domino has an associated local spatial Time(T) - which cycles in tandem with State changes even after the IFE disturbance has moved on to the next spatial position - as each domino falls to its final horizontal state. Thus the last domino will register a time of 60 units.

7. Time can advance in variable quantities e.g. $(0, 2, 0) \rightarrow (0, 2, 20)$

8. Increasing the State value required to trigger a Time change at an adjacent Space element slows down the progress of the disturbance. Thus if p is the State→Space trigger then changing p from 10 to 20 units will slow down the speed of the disturbance.

9. Note that for a given time there is some degree of Spatial localisation (e.g. for Time of 20 units the disturbance could only be found to be located at Spatial position 0,1 or 2).

3 Analysis of matter disturbance

It is often matter rather than its spatial position or the time associated with that matter that is defined to constitute the identity of a thing. However, at the microscopic level, a different viewpoint is required.

(Ship 1). Both ships represent two parallel continuities of identity. This forms a useful model as an entity can be conceived in two alternative spatial positions at the same time. How we regard the identity of an entity therefore affects both what and where we presume that entity to be. In particular, an entity can be viewed as at two different points in space at the same time, dependent on how we have tracked and how we collapse its identity

A hypothetical subatomic particle (a theoretical unit particle without sub-components) can be defined in terms of its Energy e, Space position x, and Time T. It will be convenient to substitute the concept of energy with that of State R where *energy is defined as the rate of change of State.* If State change is quantised and the smallest unit of State change is dR, then a variable of *time* specifies the energy such that $e = \frac{dR}{dt}$ where dt is the time taken for the State change.

An important principle can be inferred. Let the matter be observed from one moment to the next. If nothing at all has changed in the State of the matter[5] it will be assumed that time will not have progressed from the point of view of the matter, which defines a stringent notion of invariance. A change in time can *only* be associated with a change in State or a change in Space. The following assumptions are therefore made:

(i) Time, Space and State advance in quantised units
(ii) Time can only advance when change occurs
(iii) change can only occur if there is either or both:
 (a) change in State position
 (b) change in Spatial position

1. There cannot *logically* be a change in Time without a change in either State or Space. Causally, for a given entity in a specific fixed spatial position, then with no change in State *there can be no change in Time.* If an entity changes spatial position or an entity changes State, then either of these changes triggers an increase in Time. The earlier analysis of fans/dominos suggests that there is an issue of identity to be considered in a movement of State or Space.

2. These Time changes can be labelled as "alpha-time" for changes in State (with a unit **t'**) and "beta-time" for changes in Space (with a unit $\mathbf{t}^*$) respectively. It will not be assumed that these times are the same. These two times will be kept distinct and modelled separately as $(\alpha, \beta) = (rst', nt^*)$.

3. It will further be assumed that time can never be directly measured and that in our (phenomenal) world only State changes are ever measured - through which changes in time are *inferred.* Consequently we only ever measure alpha-time.

4. The combination of alpha-time and beta-time that determines when a State change is occurring at a particular Space position. This is central to

[5]Specifically, we require a change in the time of the viewer (which implies a change in state of the viewer) without a change in time experienced by the matter.

meetings of coincident State IFEs which determine an *interaction*.

5. Because our time measurements, based only on alpha-time, may differ from the total (alpha and beta) time, measurements of apparently coincident events will vary. Questions immediately follow as to the nature of these two components (α, β) and how they are resolved. A graph is therefore set up to model the movement of matter in Space and Time.

Progression of an energy disturbance

The entity "State" is defined as the infinite set of elements $R = \{0, h, 2h, 3h...\}$ where 0 indicates a null State, h indicates an activated State...The smallest unit of State change $dR = h$. There are an infinite number of potential States.

The entity "Space" is defined as the infinite set of elements $x = \{0, dx, 2dx, 3dx...\}$ where 0 indicates the first spatial position, dx the next spatial position to the right etc...The smallest unit of Space change is dx. Each spatial position is therefore an equal distance dx units apart.

The entity "alpha-time" is defined as the infinite set of elements $\alpha = \{0, t', 2t', 3t', 4t', ...\}$. The smallest unit of alpha-time change is t'.

The entity "beta-time" is defined as the infinite set of elements $\beta = \{0, t^*, 2^*, 3t^*, 4t^*, ...\}$. The smallest unit of beta-time change is t^*.

The Space, Space, alpha-time and beta-time entities interrelate in the matter graph: (R, x, α, β).

A directed link from State to alpha-time is defined such that *any* change in State dR triggers a change in alpha-time $d\alpha$. This is the State→alpha-time link.

A directed link from alpha-time to State is defined such that *a change in alpha-time of st' units* triggers a change in State (i.e. "it takes s units of alpha-time to transition from one State to the next"). This is the alpha-time→State link

A directed link from beta-time to State is defined such that *a change in beta-time of* t^* *units* triggers a change in State (i.e. "it takes a unit of beta-time to transition from one State to the next"). This is the beta-time→State link

A directed link from State to Space is defined such that a change of State **only where R'=ph** at a spatial position x triggers a change in beta-time element $d\beta$ at the *adjacent* spatial position x', with both time measures but not the State measure carried forward to this next spatial position. This is the State→Space link.

These features of the graph can be summarised in the table below:

IFE	**State(R=rh)**	α**Time(**α**= rst')**	**Space(x=ndx)**	β**Time**($\beta = nt^*$)
Elements	$(0, h, 2h ... \infty)$	$(0, st', 2st' ... \infty)$	$(0, dx, 2dx ... \infty)$	$(0, t^*, 2t^* ... \infty)$
Cycle Rule	cycle one element until next trigger	cycle s elements until next trigger	cycle one element until next trigger	cycle one element until next trigger
Link/trigger	dα or dβ	dR	State(R)→ ph	dx
Graph Constellation State(rh) → Space(nd) ↓↑ ↑ ↓ αTime(st') βTime(t^*)				

4 Combination of alpha-time and beta-time

Whilst alpha and beta increments in time apply *logically* in sequence, *temporally* they do not operate sequentially but simultaneously. Since they occur from the same moment, and they occur without reference to any external time, they occur "at once" and it therefore does not make sense to simply add them together. To establish the Time value at any given point in Space and State, we *do not* simply assert $T = \alpha + \beta$.

One approach might be to assert that the larger of the two time components covers both time advances. This would account for their "in parallel" progress from the same moment, but would leave the distinct features of the two components indiscernible. To combine their influence, it is postulated that alpha-time and beta-time act on distinct time *axes*. A separate argument (section on 3 dimensions of space) supports this for three dimensions of space.

To combine these coterminous advances in time, which proceed along different axes of alpha-time and beta-time into a single total time, the following hypothesis is made: that as for two axes in space these axes in time are orthogonal and hence their combination comprises a pythagorean sum into a Time magnitude $|T|$.

For an IFE disturbance with a State→Space-change trigger of p (i.e. dR with $R^+ = ph$) and an interval between State changes of st', if this disturbance has moved a distance x=ndx and at this spatial position has advanced to a State R=rh:

$$|T| = \sqrt{(nt^*)^2 + (npst' + rst')^2} \tag{1}$$

This indicates that following a series of n spatial movements, in the final nth spatial position there follows a variable r State movements. - Note that r may exceed the State→Space-change trigger point (i.e. $r > p$ is possible even though it will have triggered the spatially adjacent State). This time can be referred to as the *residual state time*.

If n is large i.e. a large distance has been travelled then the residual state time rst' term becomes insignificant and:

$$|T| \sim \sqrt{(nt^*)^2 + (npst')^2} = n\sqrt{(t^*)^2 + (pst')^2}$$

Movement of an energy disturbance

An IFE disturbance moving across a row can be compared with a stationary one.[6] Row A comprises n adjacent IFE States. In row B only two spatial positions are of concern: one at the start of the row and the second at the nth position.

To assist visualisation of the *distributed* form of the disturbance, its propagation can be imagined as a "Mexican Wave"" of football fans undulating in a stadium (i.e. each IFE State represents a discrete State of a fan standing up or sitting down *in a fixed spatial position*).

DIAGRAM 1 - disturbance moving in Space vs Spatially static

Row A	△△△△△△△△△△△△△△△△ → moving disturbance	
Row B	△ position1	△ position n

The two State IFEs in Row B measure time elapsed whilst remaining spatially stationary: their time advances by State changes only. The disturbance in Row A travels from spatial position 1 to spatial position n and also measures time elapsed.

Time measurements can be synchronised initially between the row A position 1 State IFE and the row B State IFEs at Space positions 1 and n[7].

[6] the lateral effects of entities on each other are significant (see Appendix); however in this case we shall simply use a lateral interaction to cross spatial dimensions.

[7] e.g. a disturbance is initiated to move out at the same speed left and right from the middle of row B until it interacts with the Space positions 1 and n in row B and Space position 1 in Row A which causes all three IFEs to start timing and for the position 1 IFE

When the moving disturbance in row A is adjacent to the IFE at Space position n in row B, these IFE States can interact and time measurements compared - time taken to move between single rows can be ignored if n is large.

Movement algorithm component

An algorithm can be established for the moving particle disturbance:

(i) Change in State(dR) of $\{(R, x, \alpha, \beta) \rightarrow (R^+, x, \alpha, \beta)\} \supset$ a change in alpha-time(dα) such that $\{(R^+, x, \alpha, \beta) \rightarrow (R^+, x, \alpha^+, \beta)\}$

(ii) Change in alpha-time(dα) of $\{(R, x, \alpha, \beta) \rightarrow (R, x, \alpha^+, \beta)\} \supset$ a change in State(dR) such that $\{(R, x, \alpha^+, \beta) \rightarrow (R^+, x, \alpha^+, \beta)\}$

(iii) A specific change in State(dR) of $\{(R, x, \alpha, \beta) \rightarrow (ph, x, \alpha, \beta)\} \supset$ a change in beta-time(dβ) at the adjacent space x^+ (where $x^+ = x + dx$) such that $\{(Q, x^+, \alpha, \beta) \rightarrow (Q, x^+, \alpha, \beta^+)\}$ where Q is the existing State value at (x^+,α,β) and α, β relate to the times at x [8]. Since it takes alpha-time of (pst') to cycle to the (ph) State, the alpha-time effectively defines the speed of the IFE disturbance.

(iv) Change in beta-time(dβ) of $\{(R, x, \alpha, \beta) \rightarrow (R, x, \alpha, \beta^+)\} \supset$ a change in State(dR) such that $\{(R, x, \alpha, \beta^+) \rightarrow (R^+, x, \alpha, \beta^+)\}$

This algorithm defines a disturbance which moves with a constant velocity through space and time. The disturbance has inertia and moves indefinitely with this constant velocity - until it interacts with another entity. The change in beta-time logically follows the change in alpha-time.

Interaction algorithm component

All interactions between two IFEs are defined to occur only where both IFEs have the same the same Space position AND Time Magnitude $|T|$ (combined alpha-time and beta-time).

For two IFE's A $\{(R_A, x_A, \alpha_A, \beta_A)$ with $d\alpha_A$=$(s_A t')\}$ and B $\{(R_B, x_B, \alpha_B, \beta_B)$ with $d\alpha_B$=$(s_B t')\}$ an interaction only occurs if $\{x_A = x_B\}$ AND $\{|T_A| = |T_B|\}$

The following check for an interaction is inserted in the algorithm:

if {(R,x,$|(\alpha$+d$\alpha)+\beta)|$) $\rightarrow$ (R',x,$|(\alpha$+d$\alpha)+\beta)|$}$\supset$ INTERACTION

i.e. if there is a change in State at the current Space position and Time magnitude *of when the IFE is about to be* then an interaction occurs. On an

in row A to start moving.

[8] This rule for change in State applies in tandem with IFE rule (i). Note also that adjacent Space entities will be triggered for each spatial dimension - see Appendix 2.

interaction occurring, the collapse function is initiated (see next section).

Because of its distributed nature, no definite State or Space position of an IFE disturbance exists until its final position is determined by an interaction.

Further, as the starting conditions are not known then a statistical approach must be used to calculate the probability of interaction at a particular spatial location.

Collapse algorithm component

The *distributed* nature of the IFE disturbance implies that if an interaction occurs at a precisely defined combination of State(R) and Space(x), a set of active States at Space positions remains *at the same Time Magnitude* where the specific interaction does not occur. The collapse function removes these components (where ø indicates a State null value and the initial State $R \neq ø$) and we define it as:

$[\{(R, x+dx, \alpha, \beta) \to (ø, x+dx, \alpha, \beta)\}$ OR $\{$(R,x-dx,α,β) $\to$ (ø,x-dx,α,β)$\}]$ $\supset \{(R, x, \alpha, \beta) \to (ø, x, \alpha, \beta)\}$

i.e. If a State IFE in a disturbance changes to a null State then a spatially adjacent State IFE will also go to a null State. The *logical position* of this monitoring algorithm is important. It sits in the loop which performs *single (t')* increments of alpha-time. Since this ensures continuous monitoring of adjacent cells, and *because of the precedence of logic over temporal advance* virtually instantaneous collapses of IFE functions can occur over over a wide region of space. It is true to say that "nothing moves faster than the speed of light", but the "nothing" has a reality.

The considerable debate over the process of collapse has centred on the implication for action at a distance or for "hidden variables". e.g. Von Neuman (1955) asserted that for a wave/particle its mechanism for evolution in time through space and its mechanism for collapse are necessarily different. However, the algorithm for collapse described above, deriving from the precedence of logic over time and the momentary possibility of both (R,x,α, β) and (R',x,α, β) negates this assertion.

Spatial dimensions

So far used a single spatial dimension has been used to describe the key concepts of the theory. However, the algorithm properly operates in 3 spatial dimensions which requires a further refinement. This is detailed in Appendix 2.

Summary of algorithm

The rules can be summarised in a logic loop:

LOOP $\{$(R,x,α,β) $\rightarrow$ (R',x,α,β) $\}$ $\supset$ COLLAPSECHECK; ELSE LOOP

INC $\{$(Q,x,$|(\alpha$+dα)+β)$|$) $\rightarrow$ (Q',x,$|(\alpha$+dα)+β)$|\}\supset$ INTERACT

(R',x,α,β) $\rightarrow$ (R',x,α',β)

$\{$(R,x,α,β) $\rightarrow$ (R,x,α',β)$\}$ $\supset$ $\{$(R,x,α',β)$\rightarrow$ (R',x,α',β)$\}$

$\{$(R,x,α,β) $\rightarrow$ (ph,x,α,β)$\}$ $\supset$ $\{$(Q,x',α,β) $\rightarrow$ (Q,x',α,β')$\}$

$\{$(R,x,α,β) $\rightarrow$ (R,x,α,β')$\}$ $\supset$ $\{$(R,x,α,β') $\rightarrow$ (R',x,α,β')$\}$

COLLAPSECHECK $\{$(R,x+dx,α+s,β) $\rightarrow$ ($\emptyset$,x+dx,α+s,β)$\}$ or $\{$(R,x-dx,α+s,β) $\rightarrow$ ($\emptyset$,x-dx,α+s,β)$\}$

$\supset$ (R,x,α,β) $\rightarrow$ ($\emptyset$,x,α,β) AND LOOP

S=S+t'

$\{S \neq st'\}$ $\supset$ COLLAPSECHECK; ELSE S=0 AND INC

INTERACT (R,x,α,β) $\rightarrow$ ($\emptyset$,x,α,β); LOOP

5 Properties of the disturbance

1. A moving disturbance comprises the interrelated fluctuating entities of State, alpha-Time, beta-Time and Space.

2. Each Space element is a distance dx apart from another: 0 indicates the position of the first element, 1 that of the next element ...99 the 100^{th} element etc. Hence proceeding from the first element to the nth element, the Space distance is $x = ndx$.

3 A disturbance either has positive or negative movements in Space. Thus it goes forward (x$\rightarrow$x+dx) or backward (x$\rightarrow$x-dx)in a spatial dimension.

4 Measurement of time can only be made through change of State - *i.e. this implies that only in alpha-time can be observed..*

5. Each State element is h units apart from another: 0 indicates the position of the first element, 1 that of the next (i.e. $\{0, h, 2h...\}$).[9]

6. A change in State entity dR triggers a change in alpha-time (dα=st' where s represents the Time$\rightarrow$State trigger link such that after s cycles of t' an advance in State dR is triggered). Thus the Time recorded by a particle to reach a State$\rightarrow$Space trigger point of ph is pst'.

If in a time T a disturbance with a State$\rightarrow$Space trigger of ph advances by r changes in State at the final Space position then the total time is T =

[9]Negative States can theoretically advance through $\{-h, -2h, -3h...\}$. However, they will not be discussed in this paper

(npst'+rst'+nt*).

7. All spatially local measurements of time are performed through changes in State phenomena. Each IFE disturbance can therefore ***itself measure time only through a change in alpha-time***. Each change of State triggers a local change in alpha-time where local time applies to the Space position of the disturbance.

8. It is notable that the (unresolved) total Time T=(α,β) can be represented as a complex number. Using a notation of beta-time as real and alpha-time as imaginary:

$$\underline{T} = nt^* + \imath(np + r)st' \tag{2}$$

or where $z = (p + r/n)s$:

$$\underline{T} = n(t^* + \imath zt') \tag{3}$$

9. All interactions occur at the same Time Magnitude $|\underline{T}| = \sqrt{TT^*} = \sqrt{(nt^*)^2 + (npst' + rst')^2}$. For large n the residual rst' alpha-time component (i.e. the additional State changes at a spatial position) in calculations of time magnitude can often be ignored. For increasingly small distances, however, the rst' component assumes an increasing proportion of the total Time.

10. Frequency is defined as f = $\frac{1}{\imath(st')}$. The (st') term indicates the Time to move from one State position to another.

11. Speed is defined as the rate of change of Space over Time.

$$v = \frac{ndx}{|T|} = \frac{ndx}{\sqrt{(nt^*)^2 + (npst' + rst')^2}} \tag{4}$$

12. A maximum speed is implied at which an disturbance can propagate through the Space medium. This occurs when the State→Space trigger point p is zero. i.e.

$$v_{max} = \frac{dx}{\sqrt{(t^*)^2 + (0 + \frac{rst'}{n})^2}} \approx \frac{dx}{t^*} \tag{5}$$

The denominator represents[10] the time taken to move a single spatial distance by an entity with no State changes occurring. $v_{max} = c$ is the speed of light. The constant c consequently connects the smallest possible change in spatial distance dx to the smallest discrete increase of beta-time

[10] over a reasonable (any measurable) distance: $n \gg (rst')$

t^*. The absence of alpha-time in the time magnitude explains why such a speed cannot be exceeded. For an entity (such as a photon) travelling at this speed, no time is experienced by that entity (experienced time = alpha-time = $npst'$).

13. Each change in Space triggers a change in beta-time - effectively the Time for the IFE disturbance to propagate to an adjacent Space position. Since there is empirically a fine gradation in possible speeds, then $t^* > t'$ and generally $pst' \gg t^*$ [11]

14. Wavelength $\lambda = v/f = \imath st' v$

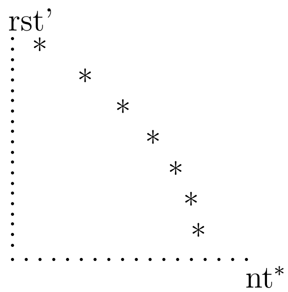
$$\lambda = \frac{\imath(dx)(st')}{\sqrt{(t^*)^2 + (pst')^2}} \tag{6}$$

15. Energy is defined as the rate of change of State. If measured at a constant spatial position the this will be the rate of change of State as measured in alpha-time (measurement of energy by a *moving* disturbance is covered in a later section). Then for a single change in state: $e = \frac{h}{(st')}$. h (Planck's constant) represents the smallest possible discrete increase in State. In a collision of two IFEs A and B with state transition times of s_A and s_B (i.e. where energies are $\frac{h}{s_A t'}$ and $\frac{h}{s_B t'}$) then in a time s_A A moves h State units and in a time $s_A s_B$ A moves $s_B h$ units; correspondingly for B in a time $s_A s_B$ B moves $s_A h$ units. Thus in a time $s_A s_B$ there is a total State change of $h(s_A + s_B)$ units. Therefore the total combined energy is: $e_{tot} = \frac{h(s_A+s_B)}{s_A s_B}$

16. The disturbance's spatial identity bifurcates at the point of the State→Space trigger. This encompasses *both* a change in alpha-time at the existing Space and a change in beta-time at the adjacent space. An ambiguity results: both where an entity is located in Space and what its State is are undefined. For a *given* time magnitude $|T|$ this ambiguity can be captured through $\sqrt{(nt^*)^2 + (npst' + rst')^2} = |T|$. Since n and r are variables, different combinations of State and Space positions can form the same Time magnitude $|T|$ from variable alpha-time and beta-time constituents. A fixed $|T|$ of magnitude $|rst'|$ forms a "temporal arc". This is easily represented for a null State→Space trigger (e.g. a photon) where p=0 (see Diagram 2 below).

[11] If there were a change in speed from $c = \frac{dx}{\sqrt{(t^*)^2+0}}$ to the next fastest speed $c' = \frac{dx}{\sqrt{(t^*)^2+(spt')^2}}$ (and setting p=s=1) then were $t' = t^*$ then $c' \sim \frac{d}{\sqrt{2(t^*)^2}} = \frac{c}{\sqrt{2}}$ which is not the case. Hence $t' \ll t^*$

DIAGRAM 2 - temporal arc for a photon at time magnitude $|rst'|$



All points on the temporal arc have the same time magnitude.

6 Time Magnitude (over large distances)

The time *measured/experienced* (alpha-time) by a spatially moving disturbance can be compared with that of a State-changing but spatially stationary one.

From the example outlined earlier in Diagram 1, the time measured by a disturbance moving in Row A from point 1 to point n in the same row can be compared with the time difference measured between stationary entities in row B at spatial points 1 and n.

Since all interactions occur at the same time magnitude then at the point of interaction at the nth spatial position, the State IFEs in both rows have the same time *magnitude*.

For the spatially moving disturbance, the time *experienced* $A_\alpha = pst'$ is simply the alpha-time $npst'$. However, because it moves spatially, then from equation (1) and assuming n is large, its time magnitude $|T|$ comprises both alpha-time and beta-time: $|T| = n\sqrt{(t^*)^2 + (pst')^2}$. The spatially stationary disturbance in the second row interacts at the same time magnitude of $|T| = n\sqrt{(t^*)^2 + (pst')^2}$. It therefore experiences *alpha-time* of $B_\alpha = |n\sqrt{(t^*)^2 + (pst')^2}|$.

Differences in experienced time between moving and stationary entities all stem from the indirect addition of beta-time. Thus $B_\alpha < A_\alpha$. For this simple reason "moving clocks run slow". This can be calculated formally.[12]

[12]The probability of an interaction at a specific spatial point will decrease with distance

The total amount of time taken by the moving disturbance in row A to move from position 1 to position n (where for convenience $z = (p + \frac{r}{n})s)$ is $T = n(t^* + \imath zt')$. The magnitude is:

$$|T| = n\sqrt{(t^*)^2 + (zt')^2} \tag{7}$$

This simple equation entirely captures the theory of special relativity, for $|T|$ expresses the total time magnitude and (zt') represents the time "experienced" by the moving IFE. To demonstrate accordance with the familiar Lorentz/Einstein model:

$$\text{Speed } v = \frac{nd}{n\sqrt{(t^*)^2 + (zt')^2}} = \frac{d}{\sqrt{(t^*)^2 + (zt')^2}} \tag{8}$$

For the photon travelling over a significant distance there is no State→Space trigger point (i.e. p=0) and r/n is very small compared with t^*. Then:

$$\text{Speed } c = \frac{nd}{nt^*} = \frac{d}{t^*} \tag{9}$$

Rearranging (7):

$$|T| = n\left(\frac{(t^*)^2}{\sqrt{(t^*)^2 + (zt')^2}} + \frac{(zt')^2}{\sqrt{(t^*)^2 + (zt')^2}}\right)$$

Substituting from (8) and (9) into the first part of the expression and rearranging the second part:

$$|T| = \frac{nv(t^*)}{c} + n(t^* zt')\frac{(zt')}{t^*}\sqrt{\frac{1}{(t^*)^2 + (zt')^2}}$$

Further rearranging:

$$|T| = \frac{nv(t^*)}{c} + n(t^* zt')\sqrt{\frac{(t^*)^2 + (zt')^2 - (t^*)^2}{(t^*)^2[(t^*)^2 + (zt')^2]}}$$

From which we obtain:

as the larger the arc the greater the probability of an interaction elsewhere on the circumference of the arc. Thus for a beam of photons, we would expect the intensity of the beam to diminish - without the energy of an individual photon being weakened.

$$|T| = \frac{nv(t^*)}{c} + n(t^* zt')\sqrt{\frac{1}{(t^*)^2} - \frac{1}{(t^*)^2 + (zt')^2}} \tag{10}$$

But from (8) and (9) we have:

$$\frac{\sqrt{c^2 - v^2}}{c} = t^*\sqrt{\frac{1}{(t^*)^2} - \frac{1}{(t^*)^2 + (zt')^2}} \tag{11}$$

Substituting this expression into (10) we obtain:

$$|T| = \frac{nv(t^*)}{c} + n\frac{\sqrt{c^2 - v^2}}{c}(zt') \tag{12}$$

Now in terms of distance travelled x:

$$x = c(nt^*)$$

Substituting into (12) we arrive at:

$$|T| = n(zt')\sqrt{1 - v^2/c^2} + (v/c^2)x$$

Since n(zt') corresponds to τ the amount of time experienced from the perspective of the moving entity (often referred to as the proper time) and $|T|$ corresponds to the time observed by a stationary observer, this is the familiar Einstein-Lorentz expression:

$$\tau = \gamma(|T| - (vx/c^2)) \text{ where } \gamma = (1 - v^2/c^2)^{-1/2} \tag{13}$$

The simplicity and explanatory power of this approach in equation (7) is notable by comparison.

All "relativistic" effects are fundamentally underpinned by time and time alone. Apparent alterations in distance arise from the perception of measured space through velocities which ultimately relate to differences in experienced time derived from combination of beta-time and alpha-time.

7 Energy viewed by a moving disturbance

If a matter source disturbance A is stationary at the origin and a matter observer disturbance B, starting from spatial position x_0, moves *away from* the source with a speed which it measures as $\frac{dx}{p_2 s_2 t'}$ then the observer will infer

the rate of change of State of the source *through changes in State directed to the observer by photons i.e. disturbances which move at the speed of light.* The apparent rate of change of State of the source will therefore depend on both the "intrinsic" rate of change of State of the source and the apparent speed of movement between the source and the observer.

To aid calculation, a time interval can be deliberately selected based on the speed of movement of the *observer*: $T_0 = pst'$ (where p is the State→Space trigger). The first State change of the source is noted by the moving observer at spatial position x_1 and the last State change of the source at the end of this interval is observed by the moving disturbance at spatial position x_2.

Because the interval of time pst' is measured *by the moving observer disturbance* which moves at speed which it perceives as $\frac{dx}{pst'}$, this implies that one "skip" of t^* will occur during this time interval which will not be experienced by the observer.

Each change of State will relay via a photon from the source to the observer at the speed of light $c = \frac{dx}{t^*}$. x_1 occurs at a coincidence (same time magnitude and spatial position) of the observer and the first photon from the first State position from the source. x_2 occurs at a coincidence between the observer and a photon emitted from the source after a source-measured time interval of pst'. For x_1 we have:

$$x_1 = \frac{dx}{t^*}t_1 = x_0 + \frac{dxt_1}{pst'} \tag{14}$$

(if the observer was moving *towards* the source then $x_1 = x_0 - \frac{dxt_1}{pst'}$)

There will be no spatial movement of the electromagnetic disturbance during the time period spent entirely on State movements by the source at the same fixed Space position.

However, an additional skip of beta-time in the observer has to be accounted for after an interval of pst' during which the photon will move. This effectively adds an extra distance of $dx = ct^*$ onto the distance travelled by the photon during the time pst' measured by the observer.

The point of coincidence between the photon and the observer occurs when both photon and observer have the same time magnitude and spatial position. Thus the apparent time *as measured by the observer*, taken for the source's State movement is *shortened to* $\sqrt{(pst')^2 - (t^*)^2}$ (which equates to pst' as measured by the source)

$$x_2 = \frac{dx(t_2 + \sqrt{(pst')^2 - (t^*)^2})}{t^*} = x_0 + \frac{dxt_2}{pst'} \tag{15}$$

Then from (14) and (15) $t_1 = \frac{x_0 t^* pst'}{dx(pst'-t^*)}$ and $t_2 = \frac{t^* pst'(x_0 - dx\sqrt{(pst')^2-(t^*)^2})}{dx(pst'-t^*)}$

$t_1 - t_2 = (pst')\frac{\sqrt{(pst')^2-(t^*)^2}}{pst'-t^*}$

The original time interval of pst' represents the period T_0 from the perspective of the unmoving source at the origin. The apparent period from the perspective of the moving disturbance will be $T' = t_2 - t_1$

i.e. $T' = T_0\frac{\sqrt{(pst')^2-(t^*)^2}}{pst'-t^*}$

And (where $e = \frac{h}{st'}$) the apparent energy $e' = e_0\frac{pst'-t^*}{\sqrt{(pst')^2-(t^*)^2}}$

Using $\frac{v}{c} = \frac{t^*}{pst'}$ then $\frac{pst'-t^*}{\sqrt{(pst')^2-(t^*)^2}} = \sqrt{\frac{(pst'-t^*)^2}{(pst')^2-(t^*)^2}} = \sqrt{\frac{pst'-t^*}{pst'+t^*}} = \sqrt{\frac{1-\frac{v}{c}}{1+\frac{v}{c}}}$

Thus $e' = e_0\sqrt{\frac{1-\frac{v}{c}}{1+\frac{v}{c}}}$.

For an observer moving towards the source, this would be: $e' = e_0\sqrt{\frac{1+\frac{v}{c}}{1-\frac{v}{c}}}$

8 Three spatial dimensions

Empirically the *speed* of a photon is isotropic in all directions. An immediate challenge arises from the *distributed* nature of the graph model.

A difference in speed would appear to arise between measurements taken in different coordinate systems. A distance dx measured along the x-axis would take time t^*, providing a speed $c = \frac{dx}{t^*}$. However, if the disturbance is measured moving in more than one spatial dimension, e.g. along the diagonal of a cube formed across x, y and z axes then the distance travelled is $\sqrt{3}dx$. Were the total time to be a sum of the three times t^* (i.e. movement occurs in a time $3t^*$) this would create a variation in the speed of the photon disturbance. There would equally be a discrepancy if the total time taken is t^*. Yet empirically the speed of a photon is constant and independent of the direction of travel.

The approach suggested by this paper is of multiple dimensions of time. If we assume that each dimension of space is associated with a separate dimension of time, then since photons have no alpha-time changes for changes in Space, allocating the *beta*-times across axes $(Re, \imath, \jmath)$ as $t^*, \imath t^*, \jmath t^*$ the total

time for a photon moving one spatial position on each spatial axis is $T = t^* + \imath t^* + \jmath t^*$. This provides a time magnitude (where for a time magnitude $|A|_{\imath\jmath}$ we calculate first the $\imath$ component and then the $\jmath$ component):

$$|T|_{ij} = |t^* + \imath t^* + \jmath t^*|_{ij} = ||t^* + \imath t^*|_\imath + |\jmath t^*|_\imath|_j = |\sqrt{2(t^*)^2} + \jmath t^*|_\jmath = \sqrt{3}t^*$$

For a distributed photon disturbance moving across the x and y and z axes, the disturbance might be found to be located (through an interaction) as having moved one spatial position *on the x axis only.* In this case the speed $= \frac{dx}{t^*}$. The disturbance might also be found to be located - again through an interaction - having moved across the x, y and z axes, in which case the speed $= \frac{\sqrt{3}dx}{\sqrt{3}t^*} = \frac{dx}{t^*}$. Thus the three dimensions of time map neatly onto the three spatial dimensions and isotropy of speed in Space-Time has been preserved.

However, for a disturbance other than a photon, State movements are implicit in Space movements and alpha-time advances necessarily occur in even a single movement across Space.

If we continue to limit to 3 time dimensions, then these alpha-time components cannot be simply allocated to the $\imath$ axis only. Were this to be the case, we would obtain: $t_x = t^* + \imath s_x t'$, $t_y = \imath t^* + \imath s_y t'$, $t_z = \jmath t^* + \imath s_z t'$ and inevitable interference would occur between the alpha-time and beta-time components.

However, if the number of time dimensions is kept to three, an elegant allocation mechanism can preserve isotropy of speed for a moving particle across three Space dimensions.

The alpha-time and beta-time components can combine in different ways on the axes. The *logical* ordering of sequences of combinations will therefore manifest accordingly.

The advance in space can be viewed as a "diagonal" progress of $|dx + dy + dz|$ and the advance in time as $|t_x + t_y + t_z|$. We can also view there being separate components that logically and temporally follow one-another. Thus $|dx| + |dy| + |dz|$ takes an amount of time $|t_x| + |t_y| + |t_z|$. The speeds measured according to either of these two methods *must be the same.*

Thus $\frac{|dx+dy+dz|}{|t_x+t_y+t_z|} = \frac{|dx|+|dy|+|dz|}{|t_x|+|t_y|+|t_z|}$

i.e. $|t_x + t_y + t_z| = \frac{\sqrt{3}}{3}\{|t_x| + |t_y| + |t_z|\} = \frac{1}{\sqrt{3}}\{|t_x| + |t_y| + |t_z|\}$

Combination requires us to consider the 12 possible alternative formulations for *logical* combination of components. Since there can only be 2 axes that combine, followed by a further combination and then a next, thus, considering x, y and z, we have in logical order:

first t_x then t_y, or first t_y then t_x

$\{(x+y)+z\}, \{(y+x)+z\}, \{(x+z)+y\}, \{(z+x)+y\}, \{(y+z)+x\}, \{(z+y)+x\}$

and in addition:

$\{z+(x+y)\}, \{z+(y+x)\}, \{y+(x+z)\}, \{y+(z+x)\}, \{x+(y+z)\}, \{x+(z+y)\}$

This requires careful co-ordination of the different time components. A movement in x and y, can be *compensated* for by a movement in the z time contribution. This requires that we divide the time movement for a single movement in space into *two* logical components of time increase i.e. $T_x = t_{x1} + t_{x2}; T_y = t_{y1} + t_{y2}; T_z = t_{z1} + t_{z2}$

The beta-time components for t_x, t_y, t_z will be along different axes $Re, \imath, \jmath$. Solution of the combination of these components can be done using:

$$t_{x1} = t^* + \jmath s_{x1} t' \ ; \ t_{x2} = \jmath t^* + s_{x2} t'$$
$$t_{y1} = -\jmath t^* + \imath\jmath s_{y1} t' \ ; \ t_{y2} = -\imath\jmath t^* + \jmath s_{y2} t'$$
$$t_{z1} = \imath t^* - s_{z1} t' \ ; \ t_{z2} = t^* - \imath s_{z2} t'$$

and through:

(i) isotropy of time: $|T_x| = |T_y| = |T_z|$

and selection of:

(ii) $s_{x1}t't^* + s_{z1}t't^* + s_{x2}t's_{z1}t' = s_{x2}t't^* + s_{y2}t't^* + s_{x1}t's_{y2}t'$

The time magnitudes of each direction component are:

$$|T_x| = |t_{x1} + t_{x2}|_{\imath\jmath} = |(t^* + s_{x2}t') + \jmath(t^* + s_{x1}t')|_{\jmath} = \sqrt{2(t^*)^2 + (s_{x1}t')^2 + (s_{x2}t')^2 + 2s_{x1}t't^* + 2s_{x2}t't^*}$$
$$|T_y| = |t_{y1} + t_{y2}|_{\imath\jmath} = \sqrt{2(t^*)^2 + (s_{y1}t')^2 + (s_{y2}t')^2 - 2s_{y1}t't^* - 2s_{y12}t't^*}$$
$$|T_z| = |t_{z1} + t_{z2}|_{\imath\jmath} = \sqrt{2(t^*)^2 + (s_{z1}t')^2 + (s_{z2}t')^2 - 2s_{z1}t't^* - 2s_{z2}t't^*}$$

The overall time magnitude is:

$|T| = |(2t^* + s_{x2}t' - s_{z1}t') + \imath(t^* - s_{z2}t') + \jmath(s_{x1}t' + s_{y2} + \imath(-t^* + s_{y1}t')\}|_{\imath\jmath}$

Thus $|T| = |[(2t^* + s_{x2}t' - s_{z1}t')^2 + (t^* - s_{z2}t')^2]^{\frac{1}{2}} + \jmath[(s_{x1}t' + s_{y2}t')^2 + (-t^* + s_{y1}t')^2]^{\frac{1}{2}}|_{\jmath}$

i.e. $|T| = [(s_{x1}t')^2 + (s_{x2}t')^2 + (s_{y1}t')^2 + (s_{y2}t')^2 + (s_{z1}t')^2 + (s_{z2}t')^2 + 6(t^*)^2 + 4s_{x2}t't^* - 4s_{z1}t't^* - 2s_{z2}t't^* - 2s_{y1}t't^* - 2s_{x2}t's_{z1}t' + 2s_{x1}t's_{y2}t']^{\frac{1}{2}}$

Using the expansions above, we have $(|T_x| + |T_y| + |T_z|)^2 = (s_{x1}t')^2 + (s_{x2}t')^2 + (s_{y1}t')^2 + (s_{y2}t')^2 + (s_{z1}t')^2 + (s_{z2}t')^2 + 6(t^*)^2 + 2s_{x1}t't^* + 2s_{x2}t't^* +$

$2s_{y1}t't^* + 2s_{y2}t't^* + 2s_{z1}t't^* + 2s_{z2}t't^* + 2|T_x||T_y| + 2|T_x||T_z| + 2|T_y||T_z|$

The multiples $2|T_x||T_y|$, $2|T_x||T_z|$ and $2|T_y||T_z|$ can be calculated:
Since $|T_x| = |T_y| = |T_z|$ we have:
$(s_{z1}t')^2 + (s_{z2}t')^2 = (s_{y1}t')^2 + (s_{y2}t')^2 - 2s_{y1}t't^* - 2s_{y2}t't^* - 2s_{z1}t't^* - 2s_{z2}t't^*$
$\sqrt{(s_{z1}t')^2 + (s_{z2}t')^2 + 2(t^*)^2} = \sqrt{|T_y|^2 + 2t^*(s_{z1}t' + s_{z2}t')} = \sqrt{|T_x|^2 + 2t^*(s_{z1}t' + s_{z2}t')}$
$(s_{z1}t')^2 + (s_{z2}t')^2 + 2(t^*)^2 = \sqrt{|T_x|^2|T_y|^2 + |T_y|^2 2t^*(s_{z1}t' + s_{z2}t') + |T_x|^2 2t^*(s_{z1}t' + s_{z2}t') + 4t^*(s_{z1}t' + s_{z2}t')^2}$
$= \sqrt{(|T_x||T_y|)^2 + (2t^*(s_{z1}t' + s_{z2}t'))^2 + 2t^*(s_{z1}t' + s_{z2}t')(|T_x|^2 + |T_y|^2)}$
$= \sqrt{|T_z|^4 + (2t^*(s_{z1}t' + s_{z2}t'))^2 + 4t^*(s_{z1}t' + s_{z2}t')(|T_z|)^2}$
$= \sqrt{(|T_z|^2 - 2t^*(s_{z1}t' + s_{z2}t'))^2} = |T_z|^2 + 2t^*(s_{z1}t' + s_{z2}t')$
$= |T_x||T_y| + 2t^*(s_{z1}t' + s_{z2}t')$
i.e. $|T_x||T_y| = (s_{z1}t')^2 + (s_{z2}t')^2 - 2t^*(s_{z1}t' + s_{z2}t') + 2(t^*)^2$
Likewise $|T_x||T_z| = (s_{y1}t')^2 + (s_{y2}t')^2 - 2t^*(s_{y1}t' + s_{y2}t') + 2(t^*)^2$
And $|T_y||T_z| = (s_{x1}t')^2 + (s_{x2}t')^2 + 2t^*(s_{x1}t' + s_{x2}t') + 2(t^*)^2$

Thus $(|T_x|+|T_y|+|T_z|)^2 = 3\{(s_{x1}t')^2 + (s_{x2}t')^2 + (s_{y1}t')^2 + (s_{y2}t')^2 + (s_{z1}t')^2 + (s_{z2}t')^2 + 6(t^*)^2 + 2s_{x1}t't^* + 2s_{x2}t't^* - 2s_{y1}t't^* - 2s_{y2}t't^* - 2s_{z1}t't^* - 2s_{z2}t't^*\}$
Using the earlier expression for $|T|$ and (ii):
$|T| = [(s_{x1}t')^2 + (s_{x2}t')^2 + (s_{y1}t')^2 + (s_{y2}t')^2 + (s_{z1}t')^2 + (s_{z2}t')^2 + 6(t^*)^2 + 2s_{x1}t't^* + 2s_{x2}t't^* - 2s_{y1}t't^* - 2s_{y2}t't^* - 2s_{z1}t't^* - 2s_{z2}t't^*]^{\frac{1}{2}}$
So $(|T_x| + |T_y| + |T_z|)^2 = 3|T_x + T_y + T_z|^2$
i.e. $|T_x| + |T_y| + |T_z| = \sqrt{3}|T_x + T_y + T_z|$
Which accords with a constant speed independent of the direction of movement. Thus:
$\frac{\sqrt{3}dx}{|T_x+T_y+T_z|} = \frac{3dx}{|T_x|+|T_y|+|T_z|}$
And isotropy of Space is preserved.

9 Speculation on Gravitation

Analysis has focused on *changes* in time magnitudes and the temporal arc formed by such intervals. However, the *total* time of a disturbance should additionally be considered.

Given that the age of the universe is estimated at at least ten billion years, the total alpha-time *of the measurable matter of the universe around us* is pretty much a constant for measurements completed in the last hundred

years. This follows because firstly experiments in our purview of a hundred years will not have any significant impact on the total time magnitude of an object. Secondly the ("heavy") objects around us do not move at speeds close to the speed of light, and therefore the alpha-times will be comparatively close to the total time magnitudes.

The focus that is required is on alpha-time. Consider that changes have already been made for some time by graviton emission - *i.e. temporal arc is already formed.* It is assumed that, just as for the variable State positions highlighted earlier, there is an equivalent for the total alpha-time of a disturbance which can be distributed across a temporal arc of the entirety of the alpha-time. A range of possible States will therefore be distributed across a temporal arc *of the entirety of the alpha-time.* A key assumption is that the States of one disturbance can impact on the States of another disturbance.

Consider two disturbances a distance r apart: an observational photon disturbance A with energy $\frac{h}{s_A t'}$ and total alpha-time T_A and a slow-moving source disturbance B with energy $\frac{h}{s_B t'}$ and a total alpha-time T_B.

The initial State of A at the first Spatial position is due to A's initial State and the State contribution of B.

To calculate this we adjust measures of Space through State changes calibrated in $s_B t'$:

i.e. initial State $= \frac{T_A h}{s_A t'} + (\sqrt{(\frac{T_B}{s_B t'})^2 - (\frac{rt^*}{dx s_B t'})^2})h$

The States of the two disturbances will, in time $(s_A t')$ as measured at A, have advanced State *at B* by $\frac{s_A t' h}{s_B t'}$ and at A by h.

Later State $= \frac{T_A h}{s_A t'} + h + (\sqrt{(\frac{T_B}{s_B t'} + \frac{s_A t'}{s_B t'})^2 - (\frac{rt^*}{dx s_B t'})^2})h$

i.e. rate of change of State of the photon in the first Space position

$$e_0 = \frac{h+(\sqrt{(\frac{T_B}{s_B t'}+\frac{s_A t'}{s_B t'})^2-(\frac{rt^*}{dx s_B t'})^2})h-(\sqrt{(\frac{T_B}{s_B t'})^2-(\frac{r\frac{t^*}{dx}}{s_B t'})^2})h}{s_A t'}$$

To calculate the change of State of the photon at the adjacent spatial position (i.e. which is a distance dx closer to the source):

Initial State $= \frac{T_A h}{s_A t'} + (\sqrt{(\frac{T_B}{s_B t'})^2 - (\frac{r\frac{t^*}{dx} - t^*}{s_B t'})^2})h$

Later State $= \frac{T_A h}{s_A t'} + h + (\sqrt{(\frac{T_B}{s_B t'} + \frac{s_A t'}{s_B t'})^2 - (\frac{r\frac{t^*}{dx} - t^*}{s_B t')})^2})h$

i.e. rate of change of State of the photon in the second Space position

$$e_1 = \frac{h+(\sqrt{(\frac{T_B}{s_B t'}+\frac{s_A t'}{s_B t'})^2-(\frac{r\frac{t^*}{dx}-t^*}{s_B t'})^2})h-(\sqrt{(\frac{T_B}{s_B t'})^2-(\frac{r\frac{t^*}{dx}-t^*}{s_B t'})^2})h}{s_A t'}$$

i.e. the difference in energy for the photon between the first and second

spatial positions is $e_1 - e_0$:

$$e_1 - e_0 = \frac{(\sqrt{(\frac{T_B}{s_Bt'}+\frac{s_At'}{s_Bt'})^2-(\frac{r\frac{t^*}{dx}-t^*}{s_Bt'})^2})h-(\sqrt{(\frac{T_B}{s_Bt'})^2-(\frac{r\frac{t^*}{dx}-t^*}{s_Bt'})^2})h-(\sqrt{(\frac{T_B}{s_Bt'}+\frac{s_At'}{s_Bt'})^2-(\frac{r\frac{t^*}{dx}}{s_Bt'})^2})h-(\sqrt{(\frac{T_B}{s_Bt'})^2-(\frac{r\frac{t^*}{dx}}{s_Bt'})^2})h}{s_At'}$$

$$= \frac{h}{s_at'}[(\frac{r\frac{t^*}{dx}-t^*}{s_Bt'})\{\sqrt{\frac{(\frac{T_B}{S_Bt'}+\frac{s_At'}{s_Bt'})^2}{(\frac{\frac{rdx}{dt^*}-t^*}{s_Bt'})^2}-1}-\sqrt{\frac{(\frac{T_B}{S_Bt'})^2}{(\frac{\frac{rdx}{dt^*}-t^*}{s_Bt'})^2}-1}\}-(\frac{r\frac{t^*}{dx}}{s_Bt'})\{\sqrt{\frac{(\frac{T_B}{S_Bt'}+\frac{s_At'}{s_Bt'})^2}{(\frac{\frac{rdx}{dt^*}}{s_Bt'})^2}-1}-\sqrt{\frac{(\frac{T_B}{S_Bt'})^2}{(\frac{\frac{rdx}{dt^*}}{s_Bt'})^2}-1}\}]$$

Using a Binomial expansion:

$$\sim \frac{h}{2s_at'}[(\frac{r\frac{t^*}{dx}-t^*}{s_Bt'})\{\frac{(\frac{T_B}{S_Bt'}+\frac{s_At'}{s_Bt'})^2}{(\frac{\frac{rdx}{dt^*}-t^*}{s_Bt'})^2} - \frac{(\frac{T_B}{S_Bt'})^2}{(\frac{\frac{rdx}{dt^*}-t^*}{s_Bt'})^2}\} - (\frac{r\frac{t^*}{dx}}{s_Bt'})\{\frac{(\frac{T_B}{S_Bt'}+\frac{s_At'}{s_Bt'})^2}{(\frac{\frac{rdx}{dt^*}}{s_Bt'})^2} - \frac{(\frac{T_B}{S_Bt'})^2}{(\frac{\frac{rdx}{dt^*}}{s_Bt'})^2}\}]$$

$$= \frac{h}{2s_At'}[(\frac{s_Bt'}{r\frac{t^*}{dx}-t^*})\{(\frac{T_B}{s_Bt'} + \frac{S_At'}{S_Bt'})^2 - (\frac{T_B}{s_Bt'})^2\} - (\frac{s_Bt'}{r\frac{t^*}{dx}})\{(\frac{T_B}{s_Bt'} + \frac{s_At'}{s_Bt'})^2 - (\frac{T_B}{s_Bt'})^2\}]$$

$$= \frac{h}{2s_At'}(\frac{s_Bt'}{r\frac{t^*}{dx}-t^*} - \frac{s_Bt'}{r\frac{t^*}{dx}})\{(\frac{T_B}{s_Bt'} + \frac{s_At'}{s_Bt'})^2 - (\frac{T_B}{s_Bt'})^2\}$$

$\sim \frac{ht^*s_Bt'}{2s_At'r^2}(2\frac{T_b}{s_Bt'}\frac{s_At'}{s_Bt'} + (\frac{s_At'}{s_Bt'})^2)$ assuming that r is very large c.f. dx

Assuming that $T_B \gg s_At'$ (where T_B is the age of the source disturbance and s_At' is the time taken for a single State change of the photon) then the change in energy of the photon:

$$e_1 - e_0 \sim \frac{hcT_Bdx}{r^2(s_At')(s_Bt')} \tag{16}$$

This energy change occurs in a time s_At'. Thus the rate of change of energy $= \frac{2hcT_Bdx}{r^2s_At's_Bt'}$

For a photon, since velocity is constant = c, change in energy relates to change in mass and Force $F = \frac{d(mv)}{dt} = c\frac{dm}{dt}$. Since $m = \frac{e}{c^2}$ then $F = \frac{1}{c}\frac{de}{dt}$ and:

$$F = \frac{hT_Bdx}{r^2(s_At')(s_Bt')} \tag{17}$$

But since $m_A = \frac{h}{s_At'c^2}$ and $m_B = \frac{h}{s_Bt'c^2}$ then $F = \frac{Gm_Am_B}{r^2}$

Thus as h, c, T_B, dx are all constants, this implies

$$G = \frac{T_Bdxc^4}{h} \tag{18}$$

dx therefore differs from the Planck distance. Assuming Planck's constant $h = 6.63X10^{-34}$ Js, speed of light $c = 3X10^8m/s$, the gravitational constant $G = 6.67X10^{-11}$ and the age of the universe T_B as approximately 10 billion years ($= 3.15X10^{17}s$) then: $dx = \frac{Gh}{T_Bc^4} \sim 1.73X10^{-95}m$ which is *much* smaller than the Planck distance.

Note that this calculation is for a change in energy for a *single* Space position movement dx. For a larger change in spatial position ndx, the calculation is considerably more complex as the changes in energy have to be *accumulated* across each spatial position and then reflected back into the calculation for the influence of $T_B + d(s_A t')$.

This calculation implies that G varies over time and is *increasing*. Additionally the gravitational force exerted by a disturbance that has been moving very fast over a long time period will be *lower* than that for a slower-moving one. The challenge is that we do not have the opportunity to measure gravitational forces produced by disturbances that have been moving very fast for a very long time as they tend to be extremely low in mass.

10 Conclusions

The multi-dimensional time approach underpins significant aspects of the theories of relativity and quantum physics - including why the speed of light has a maximum, perceived differences in experienced time for moving and stationary entities, how the concepts for the speed of light c and Planck's constant h are derived more fundamentally from the units of alpha-time and beta-time and non-localised effects involving the collapse function.

A further paper describes the statistical consequences of defined interaction at a specified Time Magnitude and the bifurcation of identity at the point of a change in Space. Computer models and discussion are available from the author on request.

11 Acknowledgements

The assistance of University College London Computer Science department is gratefully acknowledged.

12 References

(1) Feynman R (1982) "Simulating Physics with Computers",International Journal of Theoretical Physics, 21:467-488,

(2) Jeffreys H (1939): "Theory of Probability" , OUP.

(3) Gauss C F “Werke” (1863-1933), Gottingen: Gesellschaft der Wissenschafften,

(4) Jaroszkiewicz G (2000) ”Causal Implication and the Origin of Time Dilation” General Relativity and Quantum Cosmology, abstract gr-qc/0008022

(5) Minsky M (1982) “Cellular vacuum”, International Journal of Theoretical Physics, 21(6/7):537-551

(6) Olds C D, Lax A, Davidoff G (2000) “The Geometry of Numbers”, The Mathematical Association of America

(7) Pearl J (2000) “Models, Reasoning and Inference”, Cambridge University Press

(8) Tegmark (1997) “On the dimensionality of spacetime”, Classical and Quantum Gravity, 14, L69-L75

(9) Von Neumann J (1955) “Mathematical Foundations of Quantum Mechanics”, translated by R.T. Berger, Princeton. Princeton University Press.